STUDIES OF AMERICAN GINSENGS

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Between 1974 and 1978 four international symposia dealing with ginseng took place in Switzerland, Korea, and Singapore. A total of 79 papers were published in the proceedings of these symposia. Only one of them concerns the ecology and phytogeography of ginseng. The remaining reports deal with the isolation, identification, and characterization of the chemical composition of the root or leaves of ginseng, the biological effects of the ginsenosides, the clinical uses of ginseng products (especially for the revitalization of sick people or for the rejuvenation of elderly persons) and the management of the soil for increased production of ginseng. In researches concerning ginseng, botanists have lagged behind the phytochemists and pharmacologists. Consequently, in currently published books on ginseng, there are many myths, suppositions, and erroneous statements about the plant. In this article, chromosome counts, ecological, and biological observations of *Panax quinquefolius* L. and *P. trifolius* L. are reported. Much of the data has never been recorded before.

The material used for cytological examinations flowered in the greenhouse of the Arnold Arboretum, Harvard University. Four-year old roots of *Panax quinquefolius* were supplied by Mr. E. P. Robbins, Gardens of the Blue Ridges, Pineola, North Carolina. These roots were originally raised from seed collected locally. A colony of *P. trifolius* was carefully removed together with the soil about 40 cm. in diameter and 20 cm. in depth from the woods in Sharon, Massachusetts by Mr. Laurence Newcomb.

CHROMOSOME NUMBERS OF TWO AMERICAN SPECIES OF PANAX

Previously reports on the chromosome numbers of *Panax quinquefolius* were made by W. Taylor (1967) $2n = 44$ for Canadian material, and by A. Blair (1975) $2n = 48$ for specimens from Virginia. Variability in the karyotype of the tetraploid species of *Panax* in America corresponds to the findings of Asian botanists for a vicarious species *P. ginseng* C. A. Meyer, T. Sugiura (1936) $2n$

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=44, and C. Harn and J. Whang (1963) $2n$=48. It is worthy of note that H. Matsuura and T. Sutô (1935) reported the gametic number 24 for *P. japonicus* A. C. Meyer. This report has been misquoted in Darlington and Jamaki Ammal (1945), in Darlington and Wylie (1955), and in Bolhovskikh (1969) as $n = 12$.

The chromosome numbers for the American species here investigated are based on n = 12. Young flowering buds with microsporocytes were fixed for 12 hours in 3:1 alcohol/acetic acid and stained in aceto-carmine. *Panax trifolius* is found to be a diploid with $2n = 24$ (Fig. 1 A), and *P. quinquefolius* is a tetraploid with $2n = 48$ (Fig. 1 B). At meiosis regular bivalent pairing was observed in both species. Specimens for documentation of these counts are deposited in the Herbarium of the Arnold Arboretum.

ECOLOGICAL OBSERVATIONS

All the species of Panax grow on the forest floor in the shade of undisturbed deciduous woods. In New England, *Panax quinquefolius* grows in well drained soil on slopes on the northern side of hills along streams above the flood level. The associated trees are *Acer pensylvanicum* L., *A. rubrum* L., *A. saccharum* Marsh., *Betula lenta* L., *Betula lutea* Michx. f., *B. papyrifera* Marsh., *Carya ovata* (Miller) K. Koch, *Fagus grandifolia* Ehrh., *Fraxinus americana* L., *Liriodendron tulipifera* L., *Quercus rubra* L., *Tsuga canadensis* (L.) Carr., and *Tilia americana* L. The shrubs in the association are *Hamamelis virginiana* L., *Kalmia latifolia* L., *Lonicera canadensis* Bartr., *Parthenocissus quinquefolia* (L.) Planch., and *Virburnum acerifolium* L. The herbaceous species in the association include ferns and fern-allies, and many perennial dicots and monocots. Among these are *Adiantum pedatum* L., *Botrychium virginianum* (L.) Sw., *Polystichum acrostichoides* (Michx.) Schott, *Actaea pachypoda* Ell., *Allium tricoccum* Ait., *Arisaema triphyllum* (L.) Schott, *Asarum canadense* L., *Caulophyllum thalictroides* (L.) Michx., *Clintonia borealis* (Ait.) Raf., *Dentaria diphylla* Michx., *Medeola virginiana* L., *Sanguinaria canadensis* L., *Uvularia perfoliata* L., *Viola pensylvanica* Michx. and *V. rostrata* Pursh.

Panax trifolius, dwarf ginseng, grows very abundantly on flat wet land and along small streams. The dominant trees associated with the species are *Acer rubrum* L., *Betula lutea* Michx. f., *Cornus*

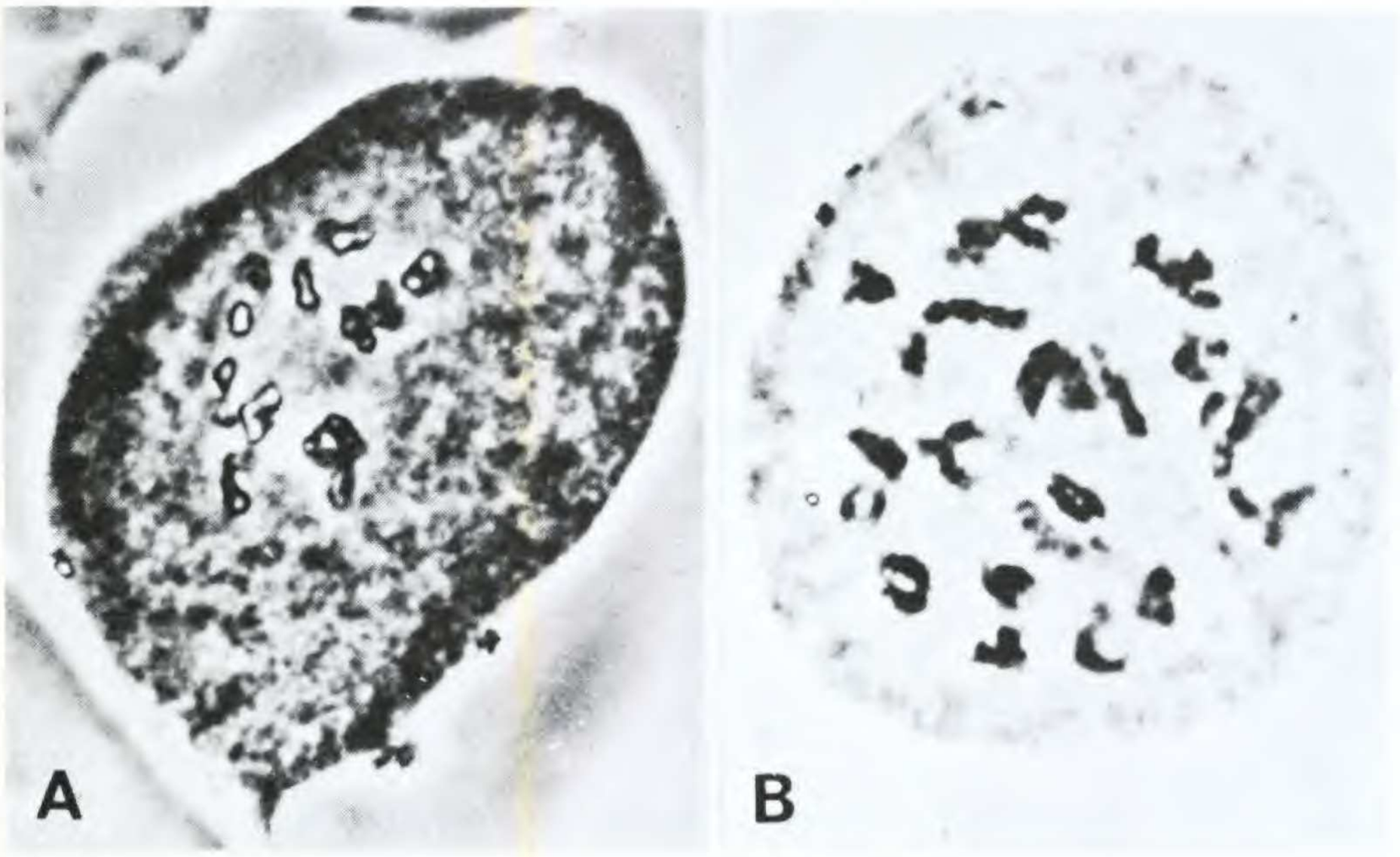

Figure 1. Dividing microsporocytes of *Panax:* A. *Panax trifolius*, $n = 12$, metaphase I (voucher specimen *S. Y. Hu 13943);* B. *Panax quinquefolius*, $n = 24$, diakinesis (voucher specimen *S. Y. Hu 13945).*

florida L., *Fraxinus americana* L., *Ostrya virginiana* (Miller) K. Koch, and *Quercus rubra* L. The shrubs in the association are *Amelanchier canadensis* (L.) Medic., *Gaylussacia frondosa* (L.) Torr. & Gray, *Hamamelis virginiana* L., *Rubus hispidus* L., *Virburnum acerifolium* L., *V. angustifolium* Ait., and *V. recognitum* Fern. The herbs in the association are *Anemone quinquefolia* L., *Arisaema triphyllum* (L.) Schott, *Impatiens capensis* Meerb., *Maianthemum canadense* Desf., *Medeola virginiana* L., *Ranunculus recurvatus* Poir, *Solidago caesia* L., and *Uvularia sessilifolia* L. The ferns and fern-allies commonly in the association are *Athyrium filix-feminia* (L.) Roth, *Dryopteris novoboracensis* (L.) Gray, *Lycopodium complanatum* L., *L. obscurum* L., *Osmunda claytoniana* L., and *O. cinnamomea* L. Some of the ferns grow very proliferously and many of them are very close to the dwarf ginseng. Fortunately for the ginseng, the ferns commence their annual development later than the ginseng, and by the time their fronds are fully grown to cover the ginseng, the latter has reached the dormant stage, with the mature fruits fallen to the soil, and the tuber hidden in the earth.

BIOLOGICAL OBSERVATIONS

Little is known about the growing habit of the species, the structure of the population, or the longevity of the individual of ginseng. The species of ginseng are all deciduous perennial herbs, with a subapical bud on a subterranean rhizome. The aerial portion of a plant becomes yellow, dies, and disappears at the end of the growing season. Some of the Asian species of *Panax* have creeping rhizomes with slender elongated or stout short internodes without fleshy roots for storage. Both American species have fleshy roots and short suberect rhizomes. Normally one scar is added to the rhizome each year by the deciduous aerial portion, thus the scars on a rhizome serve as a criterion for estimating the age of the plant. The size of the scars on the rhizome depends upon the area of contact between the aerial growth and the rhizome. In *P. quinquefolius* the scars are usually distinct, while in *P. trifolius* the scars are very small. Moreover, the bud-scales of *P. trifolius* are quite persistent, and this condition gives added difficulty in determining the age of a plant.

The aerial portion of ginseng has been regarded as a stem, thus Fernald (1950, p. 1077) said, ". . . the erect simple stems bearing a solitary whorl of 3 palmate leaves." There are also botanists who regard the rhizome as a sympodium and the aerial growth as a compound leaf with an epiphyllous flowering umbel.

Panax quinquefolius resumes growth in the middle of June. The flower-buds and leaves emerge simultaneously. The flowers are relatively small, yellowish, with erect petals and anthers spreading out between them. A varying number of flowers bear one- or two-seeded fruits, which mature to a deep red color in early September. The mature fruits drop mostly near the parent plant, and in nature *P. quinquefolius* usually grows in colonies. The embryo of ginseng is poorly developed at the maturity of the fruit. When the fruits drop to the ground in September, the weather is cold. The underdeveloped embryo remains inactive during this first winter. It develops into a mature embryo at the next growing season, and passes the second winter for the chilling requirement. Germination takes place the following spring, eighteen months after the fruit has ripened. Growers know that ginseng seeds take eighteen or more months to germinate.

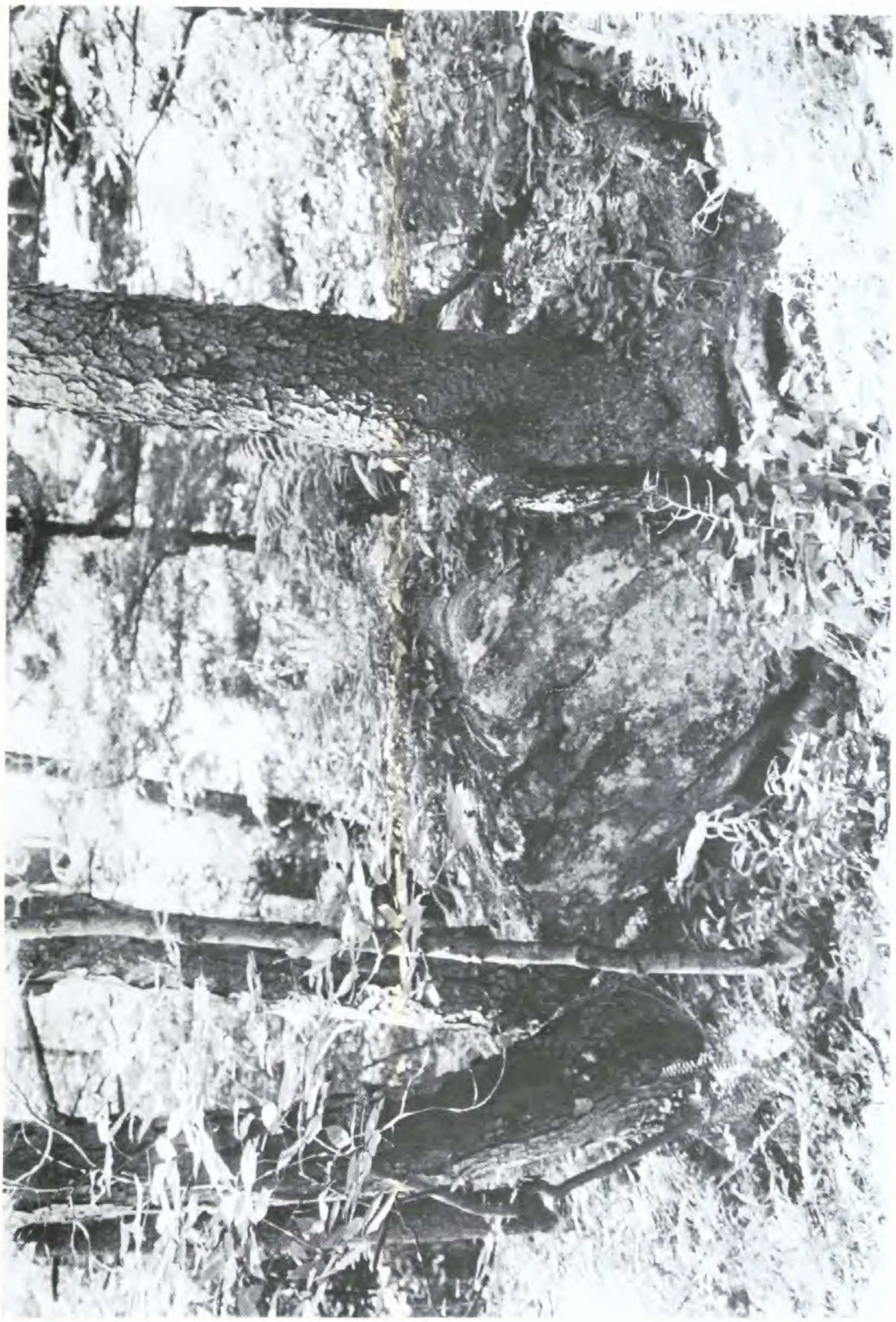

Figure 2. Ecological background of a colony of natural stand of *Panax quinquefolius* (see text for explanations.)

Panax trifolius resumes growth between mid-April and early May, with the flowers fully open by May 10th. The plants are mostly unisexual with the male plants bearing white flowers on slender pedicels 4 or 5 times longer than the obconic hypanthia, and the female plants bearing pinkish flowers on stout and short pedicels about as long as the urceolate hypanthia. By early to middle June, the three-seeded fruits mature and shatter, dispersing the seeds 1–10 mm. from the parent plant. Each seed contains an underveloped embryo which has a warm season during which it matures. The seeds of *P. trifolius* take the chilling requirement in the winter and germinate in the next growing season.

Comparing *Panax quinquefolius* and *P. trifolius* it seems that the latter species requires a shorter period of dormancy because of a difference in the timing of its seed ripening, rather than a difference in actual dormancy mechanism.

Panax trifolius is adapted to a very short growing season, completing its life cycle in about six weeks when the ground is warm but before the leaves of trees and ferns become fully expanded and shade out the forest floor. In general, *P. trifolius* is more tolerant of cool temperature, wet soil, and strong light than *P. quinquefolius*.

A POPULATION STUDY

In a wooded area of northwestern Connecticut, there is an undisturbed colony of *P. quinquefolius* (Fig. 2). The largest ginseng plant in this area is over 30 years old. The data for the population study were collected there.

An Old Ginseng: A large ginseng plant growing by a yellow birch (Fig. 2, right front) was examined. This plant has a carrot-like taproot and four adventitious roots. The first of these emerged very early in the life of the plant and it is so close to the taproot that it appears to be a branch of it. The other adventitious roots emerged much later and at different intervals. They seem to function in supporting the rhizome, which tends to bend after attaining a certain length. The number of the scars on the rhizome shows that the plant is about 32 years old (Fig. 3).

Vigor of American Ginseng: An understanding of the vigor of *P. quinquefolius* helps botanists and environmentalists to evaluate whether it is an endangered species. In 1972 a quadrat of a meter

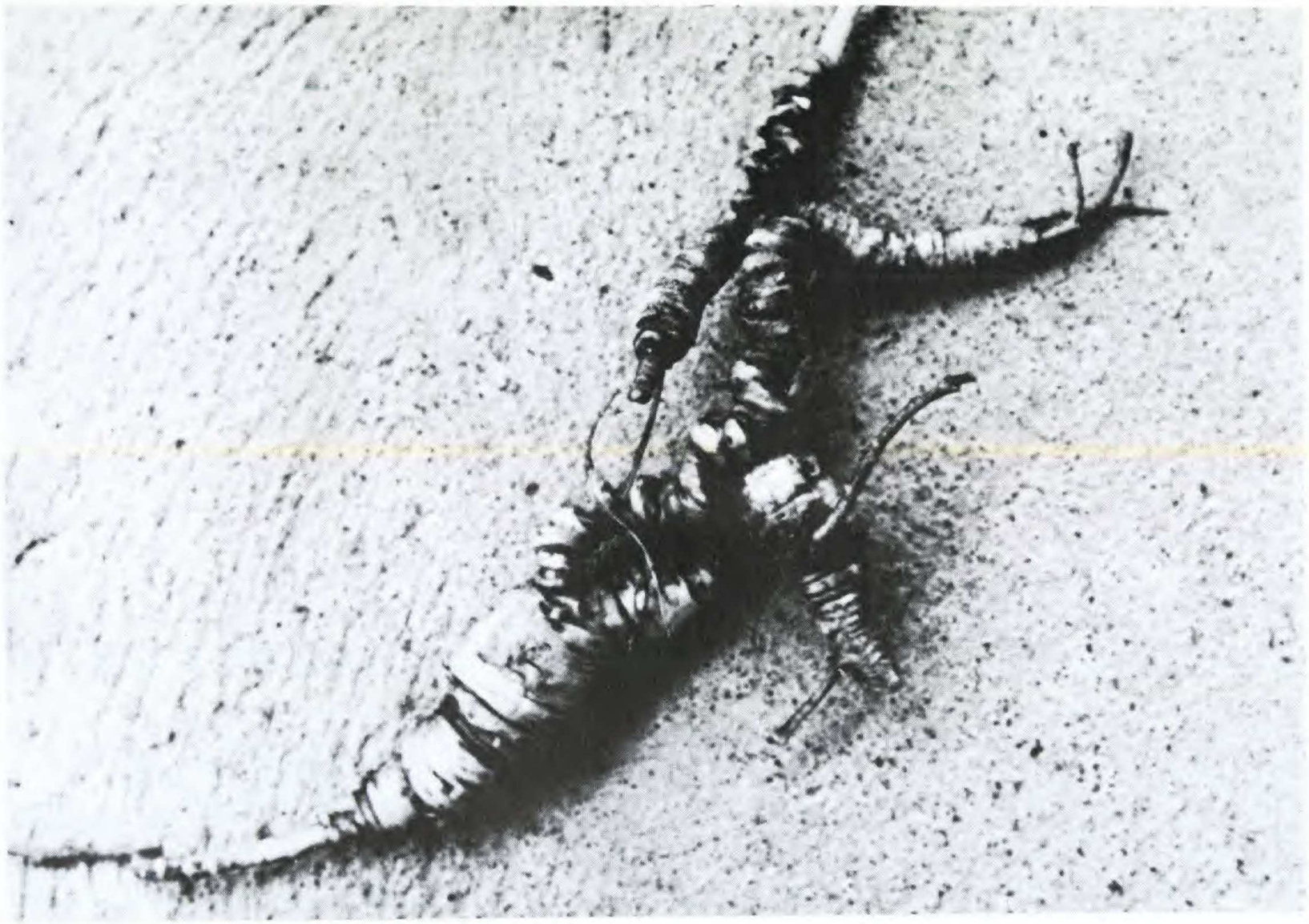

Figure 3. The subterranean portion of a 32-year old American ginseng showing the carrot-like taproot, the zigzag rhizome with adventitious roots, and a portion of the aerial growth.

square containing 24 plants of *P. quinquefolius* was mapped. The area was not disturbed in subsequent years. In 1979, only ten of the original plants remained, and one new seedling was added to the quadrat. Evidently, in an interval of seven years, 41.7% of the population survived.

The number of leaves on the aerial shoot and the number of flowers on each plant were recorded. The data of the initial and the last years are given in Table 1.

Table 1. Vigor of Panax quinquefolius

Survival	1972		1979	
Plants	Leaves	Flowers	Leaves	Flowers
1	2	4	2	6
2	2	4	3	9
3	3	7	3	13
4	2	3	2	4
5	1	0	1	0
6	1	0	1	0
7	2	7	2	3
8	3	6	2	3
9	2	4	1	2
10	2	3	1	0
11	—	—	2	—

The surviving plants in the plot can be grouped into four categories. Plants 1 to 4, representing 16.7% of the original 24 plants in the quadrat, have either more leaves or flowers than they had seven years ago. Plants 5 and 6 (8.3% of the original) remain unchanged. Plants 7 to 10 (16.7% of the original populations) show reduced vigor as shown in the number of the leaves or flowers. Plant number 11 (4.2% of the original population) is a new seedling.

This natural population of *P. quinquefolius* has a very high death rate (58.3% of the population of the patch), and a very low (4.2% of the original number of individuals) rate of reproduction. High death rate of cultivated *P. quinquefolius* has been observed in a plantation in Needham, Massachusetts, where approximately two thousand four-to seven-years' old ginseng disappeared in three years. The cause of such high death rate awaits further investigation. Some of the survivors in the natural population observed have increased in vigor during the seven year period, some have reduced vigor, and a

small number remains unchanged. This study also shows that the number of leaves of ginseng at the flowering stage is two or three, and the number of flowers per umbel vary from two to thirteen.

SUMMARY

Ginseng is of special interest to environmentalists because it is a rare and significant species which requires protection, to commerce because it is an high-value item in international trade, and to botanists because there is much knowledge about the species to be discovered. To environmentalists this article presents data on a high death rate and low reproduction of *P. quinquefolius* in nature. To persons interested in ginseng business we point out that there is a species, *P. trifolius*, which can tolerate colder climate, stronger light, and wetter soil, and which requires a shorter period of dormancy. To botanists we suggest the introduction of the superior characters of the hitherto neglected *P. trifolius* into the genetic system of *P. quinquefolius* and *P. ginseng* through hybridization and selection, and the investigations of its contents and possible beneficial uses for man.

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